# PREDICTION OF GREY WATER FOOTPRINT OF SUNGAI LEMBING, BUKIT SAGU AND BUKIT UBI WATER TREATMENT PLANTS

SITI FAZLINA BINTI MOHD SUHAIMI

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

## SUPERVISOR'S DECLARATION

I/We* hereby declare that I/We* have checked this thesis/project* and in my/our* opinion, this thesis/project* is adequate in terms of scope and quality for the award of the degree of *Doctor of Philosophy/ Master of Engineering/ Master of Science in ……..

_____

(Supervisor's Signature)

Full Name :

Position :

Date :

_____

(Co-supervisor's Signature)

Full Name :

Position :

Date :

## STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

_____

(Student's Signature)

Full Name : SITI FAZLINA BINTI MOHD SUHAIMI

ID Number : AA15168

Date : 31st MAY 2019

# PREDICTION OF GREY WATER FOOTPRINT OF SUNGAI LEMBING, BUKIT SAGU AND BUKIT WATER TREATMENT PLANTS

SITI FAZLINA BINTI MOHD SUHAIMI

Thesis submitted in fulfillment of the requirements
for the award of the
B. Eng (Hons.) Civil Engineering

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

MAY 2019

## ACKNOWLEDGEMENTS

Thanks to Almighty Allah for giving me strength and ability to understand learn and complete this report.

I would like to express my deep gratitude to Dr Edriyana binti A.Aziz, my research supervisors, for her patient guidance, enthusiastic encouragement and useful critiques of this research work. I would also like to thank Mohd Syazwan Nizam bin Mohd Moni for his advice and assistance in keeping my progress on schedule.

My grateful thanks are also extended to all my friends especially Siti Ainifatihah binti Noor Hazlim and Ruziana binti Kamarzaman for the stimulating discussions, for the sleepless nights we were working together before deadlines, and for all the fun we have had in the last four years.

Finally, I wish to thank my parents for their support and encouragement throughout my study.

# ABSTRAK

Faktor terpenting yang mempengaruhi kekurangan air di dalam dan luar negara dan ketersediaan sumber air tawar bukan sahaja penduduk dunia yang semakin berkembang tetapi juga peningkatan permintaan air. Dari kajian ini, tahap pencemaran air di lembah sungai Kuantan direkodkan mengikut setiap loji rawatan air (WTP) dan penilaian jejak air kelabu digunakan sebagai pendekatan untuk mengira jumlah air tawar yang digunakan untuk mengasimilasi kepekatan pencemar. Oleh itu, kajian ini bertujuan untuk mengira jejak air kelabu keseluruhan, untuk meramalkan trend keseluruhan jejak air kelabu dan membandingkan algoritma terbaik antara Rangkaian Neural Buatan (ANN) dan Bayesian Networks (BN) dalam ramalan jejak air kelabu di Sungai Lembing WTP, Bukit Sagu WTP dan Bukit Ubi WTP pada tahun 2015 hingga 2017. Sebagai hasil akhir kajian ini, jumlah air kelabu di Sungai Lembing, Bukit Sagu dan loji rawatan air Bukit Ubi di lembah sungai Kuantan dikira. Trend ramalan keseluruhan jejak air kelabu dalam tiga loji rawatan air telah dapat dihasilkan sebagai hasil akhir kajian. Algoritma Rangkaian Neural Buatan (ANN) juga dipilih sebagai algoritma terbaik.

## ABSTRACT

The most important factors affecting water scarcity in local and global and the availability of fresh water resources are not only a growing world population but also an increasing water demand. From this study, the level pollution of water in Kuantan river basin is recorded according to each water treatment plant (WTP) and grey water footprint assessment was used as an approach to account the total amount of freshwater used to assimilate the pollutant's concentration. Hence, this study is aimed to calculate the total grey water footprint, to predict the trend of total grey water footprint and to compare the best algorithm between Artificial Neural Network (ANN) and Bayesian Networks (BN) in grey water footprint prediction at Sungai Lembing WTP, Bukit Sagu WTP and Bukit Ubi WTP in 2015 until 2017. As the end result of this study, the total grey water footprint in Sungai Lembing, Bukit Sagu and Bukit Ubi water treatment plant in Kuantan river basin is calculated. Prediction trend of total grey water footprint in three water treatment plants has able to be produced. Artificial Neural Network (ANN) algorithm is also be chosen as the best algorithm.

## TABLE OF CONTENT

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF SYMBOLS

| | |
|---|---|
| $Fe^{2}$ | Iron |
| $m^{3}/s$ | Meter cubic per second |
| L | Load of pollutant |
| NO3-N | Nitrate-nitrogen |

## LIST OF ABBREVIATIONS

| | |
|---|---|
| ANN | Artificial Neural Network |
| BN | Bayesian Networks |
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| LOCF | Last Observation Carried Forward |
| JPS | Jabatan Pengairan dan Saliran Pahang |
| MMD | Malaysian Meteorological Department |
| PAIP | Pengurusan Air Pahang Berhad |
| RMSE | Root Mean Square Error |
| WF | Water Footprint |
| WFgrey | Grey Water Footprint |
| WTP | Water Treatment Plants |
| WEKA | Wakaito Environment for Knowledge Analysis |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Water is most important substance for all living things include plants and animals to survive on the earth. People depend on water not only for drinking but also cooking, washing, carrying away wastes and other domestic needs. Water is an important factor of production contributing both directly and indirectly to economic activity across all sectors and regions of the global economy (Distefano & Kelly, 2017). Potable water or water that is safe for drinking must be free of germs and chemicals and be clear because water is a good carrier of disease germs. When the water becomes non-potable or contaminated, people can get serious illnesses if they keep use this polluted water. Diseases that produce bacteria, toxic substances and excessive amounts of minerals and organic matter should be avoided and overcome because the water used by the public must be clean and safe. Therefore, water purification works are very important to ensure that all impurities and bacteria from the air are removed and make it healthy. Water supply systems must also meet requirements for public, commercial, and industrial activities. In all cases, the water must fulfil both quality and quantity requirements.

Water supply system gets water from an assortment of areas after proper treatment; including groundwater (aquifers), surface water, for example, lakes and streams, and the ocean through desalination. Water treatment plant is the process of converting raw water which the water is taken from the river to clean water supply to the residence areas. Raw water is full of contaminants including bacteria, chemicals and other toxins. Its treatment aims to reduce the contaminants to acceptable levels to make the water safe for people to use. Therefore, water treatment plant is needed to treat raw

water. The overview of water treatment plant is first take the raw water from river and it is treated with alum, lime, fluoride, chlorine. Then it has to undergo the process of filtration, send to the master station and remove the sludge in the water before distributed to the consumers.

The most important factors affecting water scarcity in local and global availability of fresh water resources not only pollution and climate change but also a growing world population and an increasing water demand. The increasing demand for fresh water is the main challenge to sustain water utilization all over the world. Freshwater represents to 2.5% of Earth's water and is progressively threatened by human activity and climate change (Distefano & Kelly, 2017). Water has been largely studied by engineers in Jordan, while little research has adopted a discourse analysis procedure to water scarcity in the country (Hussein, 2018). While the concept of water scarcity is generally current topic, it is the difficulty of getting sources of clean water for utilize amid a period of time and may result in encourages reduction and disintegration of accessible water resources. The total energy and water use in China has been clearly increasing in the last decades as China has been experiencing a dramatic economic development (Xu, Li, & Lu, 2017).

An increasing number of studies have been carried out since in 1990s, to quantify and to investigate the existing differences between water demand, water supply and the geographical distance between them, the concepts of water footprint and virtual water trade (Arto, Andreoni, & Rueda-Cantuche, 2016). The water footprint (WF) of a product or process was introduced for the first time in 2003 and is defined as the volume of freshwater consumed and polluted to produce a product. The water footprint is further analysed in three parts: the blue, green and grey water footprints. The blue WF is an indicator of the surface water or groundwater consumption, which includes the evaporated water, incorporated into the product, and lost return flow. The green WF is defined as the consumption of water from precipitation that is stored in the soil and does not run off or recharge the ground-water and thus, is available for evapotranspiration of plants. Finally, the grey WF of a process step indicates the degree of freshwater pollution that can be associated with the process step. The grey WF is defined as the volume of freshwater that is required to assimilate the load of pollutants

based on natural background concentrations and existing ambient water quality standards (A Y Hoekstra & Mekonnen, 2011).

## 1.2 Problem Statement

It is necessary to have a knowledge of water resource consumption and pollution during the life cycle of energy production to reduce water consumption (Ding, Liu, Yang, & Lu, 2018). Water treatment plants at Sungai Lembing, Bukit Sagu and Bukit Ubi in Kuantan River Basin have enough water quantity but using ineffective long-term the management. Inadequate infrastructure and resources will bring problems in handling wastewater management efficiently and sustainably for the majority of cities in developing countries (Ding et al., 2018). According (Cha, Son, Hong, An, & Part, 2017), one of measures against water depletion and degradation by human activities by applied the efficient water management. In addition, the data for overall water which includes rain and evaporation also is not recorded. The data are important for any researches as this data can give a solution to any problems that comes from the water.

An increasing in demand for water and a decrease in availability and quality will affect the freshwater scarcity and pollution will be aggravated problems in the future (Ercin & Hoekstra, 2014). The Intergovernmental Panel on Climate Change (IPCC) reported that unabated climate change has the potential to strongly impact freshwater resources with wide ranging consequences for societies and ecosystems(Murray, Foster, & Prentice, 2012).

Water Footprints can be analysed as blue, green or grey water footprints. According to (Zhi, Yang, Yin, Hamilton, & Zhang, 2015) this sustainability analysis should be conducted for a river basin which is the common spatial unit in water planning process. Blue water footprints relate to the consumptive use of surface and groundwater, whereas green water footprints refer to the use of rainwater that ends up as runoff and does not replenish underground water supplies. Grey water footprint is an indicator of the level of freshwater pollution associated to a stage of a particular process. It is defined as the freshwater volume required assimilating the pollutant load, given the natural background concentration and existing ambient water quality standards. For this study, we will use grey water footprints as the indicator considering

## REFERENCES


Agudosi, E. S., Abdullah, E. C., Mubarak, N. M., Khalid, M., Pudza, M. Y., Agudosi, N. P., & Abutu, E. D. (2018). SC. *Biochemical Pharmacology*. https://doi.org/10.1016/j.jece.2018.11.001

Aldaya, M. M., Chapagain, A. K., Hoekstra, A. Y., & Mekonnen, M. M. (2011). *The Water Footprint Assessment Manual*. *Earthscan*. https://doi.org/978-1-84971-279-8

Allocca, V., Marzano, E., Tramontano, M., & Celico, F. (2018). Environmental impact of cattle grazing on a karst aquifer in the southern Apennines (Italy): Quantification through the grey water footprint. *Ecological Indicators*, *93*(April), 830–837. https://doi.org/10.1016/j.ecolind.2018.05.075

Arto, I., Andreoni, V., & Rueda-Cantuche, J. M. (2016). Global use of water resources: A multiregional analysis of water use, water footprint and water trade balance. *Water Resources and Economics*, *15*, 1–14. https://doi.org/10.1016/j.wre.2016.04.002

Ascione, F., Bianco, N., Stasio, C. De, Maria, G., & Peter, G. (2017). Arti fi cial neural networks to predict energy performance and retro fi t scenarios for any member of a building category : A novel approach. *Energy*, *118*, 999–1017. https://doi.org/10.1016/j.energy.2016.10.126

Bendtsen, M., & Peña, J. M. (2016). International Journal of Approximate Reasoning Gated Bayesian networks for algorithmic trading. *International Journal of Approximate Reasoning*, *69*, 58–80. https://doi.org/10.1016/j.ijar.2015.11.002

Bogomolny, A. (2015). What Is Algorithm? *Cut-the-Knot.Org*. Retrieved from http://www.cut-the-knot.org/WhatIs/WhatIsAlgorithm.shtml

Brown, A., Matlock, M. D., & Ph, D. (2011). A Review of Water Scarcity Indices and Methodologies.

Cha, K., Son, M., Hong, S., An, S., & Part, S. (2017). Method to assess water footprint, a case study for white radishes in Korea. *International Soil and Water Conservation Research*, *5*(2), 151–157. https://doi.org/10.1016/j.iswcr.2017.02.005

Chen, Q., Norcio, A. F., & Wang, J. (2000). Neural network based stereotyping for user profiles. *Neural Computing and Applications*, *9*(4), 259–265. https://doi.org/10.1007/s005210070003

Cities, S., Zambonelli, F., Salim, F., Loke, S. W., & Meuter, W. De. (2018). [E] Algorithmic Governance in Smart Cities, (June).

Ding, N., Liu, J., Yang, J., & Lu, B. (2018). Water footprints of energy sources in China : Exploring options to improve water ef fi ciency. *Journal of Cleaner Production*, *174*, 1021–1031. https://doi.org/10.1016/j.jclepro.2017.10.273

Distefano, T., & Kelly, S. (2017). Are we in deep water? Water scarcity and its limits to economic growth. *Ecological Economics*, *142*, 130–147. https://doi.org/10.1016/j.ecolecon.2017.06.019

Du, H., Chen, W., Zhu, Q., Liu, S., & Zhou, J. (2018). Identification of weak peaks in X-ray fluorescence spectrum analysis based on the hybrid algorithm combining genetic and Levenberg Marquardt algorithm. *Applied Radiation and Isotopes*, *141*(July), 149–155. https://doi.org/10.1016/j.apradiso.2018.07.009

Duan, Z. H., & Poon, C. S. (2014). Properties of recycled aggregate concrete made with recycled aggregates with different amounts of old adhered mortars. *Materials and Design*, *58*, 19–29. https://doi.org/10.1016/j.matdes.2014.01.044

Ercin, A. E., & Hoekstra, A. Y. (2014). Water footprint scenarios for 2050 : A global analysis. *Environment International*, *64*, 71–82. https://doi.org/10.1016/j.envint.2013.11.019

Fuller, K. D., Gordon, R., Grimmett, M., Fillmore, S., Madani, A., Vanroestel, J., … George, E. S. (2010). Agriculture , Ecosystems and Environment Seasonal and crop rotational effects of manure management on nitrate – nitrogen leaching in Nova Scotia. *"Agriculture, Ecosystems and Environment," 137*(3–4), 267–275. https://doi.org/10.1016/j.agee.2010.02.012

Gillespie, T. (2012). The Relevance of Algorithms, (Light 1999).

Giwa, A., Daer, S., Ahmed, I., Marpu, P. R., & Hasan, S. W. (2016). Journal of Water Process Engineering Experimental investigation and artificial neural networks ANNs modeling of electrically-enhanced membrane bioreactor for wastewater treatment. *Journal of Water Process Engineering*, *11*, 88–97. https://doi.org/10.1016/j.jwpe.2016.03.011

Guidelines, S. (2013). R ESEARCH R EPORT S ERIES N O . 65.

Herath, I., Green, S., Singh, R., Horne, D., Zijpp, S. Van Der, & Clothier, B. (2013). Water footprinting of agricultural products : a hydrological assessment for the water footprint of New Zealand ' s wines. *Journal of Cleaner Production*, *41*, 232–243. https://doi.org/10.1016/j.jclepro.2012.10.024

Hoekstra, A. Y., & Mekonnen, M. M. (2011). National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption. Value of Water Research Report Series No. 50. *Delft, the Netherlands: UNESCO-IHE*.

Hoekstra, A. Y., & Mekonnen, M. M. (2012). The water footprint of humanity, *109*(9).

https://doi.org/10.1073/pnas.1109936109

Hussein, H. (2018). Lifting the veil: Unpacking the discourse of water scarcity in Jordan. *Environmental Science and Policy*, *89*(March), 385–392. https://doi.org/10.1016/j.envsci.2018.09.007

İçen, D., & Ersel, D. (2019). A new approach for probability calculation of fuzzy events in Bayesian Networks. *International Journal of Approximate Reasoning*, *108*, 76–88. https://doi.org/10.1016/j.ijar.2019.03.004

Jackson, C., & Mosleh, A. (2016). Bayesian inference with overlapping data: Reliability estimation of multi-state on-demand continuous life metric systems with uncertain evidence. *Reliability Engineering and System Safety*, *145*(October 2015), 124–135. https://doi.org/10.1016/j.ress.2015.09.006

Kozaki, Daisuke & Idayu Binti Harun, Norhasmira & Ab. Rahim, Mohd Hasbi & Mori, Masanobu & Nakatani, Nobutake & Tanaka, K. (2017). Determination of Water Quality Degradation Due to Industrial and Household Wastewater in the Galing River in Kuantan, Malaysia Using Ion Chromatograph and Water Quality Data. *Environments*.

Miglietta, P. P., Toma, P., Fanizzi, F. P., Donno, A. De, Coluccia, B., Migoni, D., … Serio, F. (n.d.). A Grey Water Footprint Assessment of Groundwater Chemical Pollution : Case Study in Salento. https://doi.org/10.3390/su9050799

Murray, S. J., Foster, P. N., & Prentice, I. C. (2012). Future global water resources with respect to climate change and water withdrawals as estimated by a dynamic global vegetation model. *Journal of Hydrology*, *448–449*, 14–29. https://doi.org/10.1016/j.jhydrol.2012.02.044

Naderpour, H., Hossein, A., & Fakharian, P. (2018). Compressive strength prediction of environmentally friendly concrete using arti fi cial neural networks, *16*(October 2017), 213–219. https://doi.org/10.1016/j.jobe.2018.01.007

Ridoutt, B. G., & Pfister, S. (2010). A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity, *20*, 113–120. https://doi.org/10.1016/j.gloenvcha.2009.08.003

Rosegrant, M. W., Cai, X., & Cline, S. A. (2002). *World water and food to 2025: dealing with scarcity*. Intl Food Policy Res Inst.

Safa, B., Arkebauer, T. J., Zhu, Q., Suyker, A., & Irmak, S. (2018). Latent heat and sensible heat fl ux simulation in maize using arti fi cial neural networks. *Computers and Electronics in Agriculture*, *154*(September), 155–164. https://doi.org/10.1016/j.compag.2018.08.038

Salah, H. A., Mocanu, M., & Florea, A. (2014). Analysis of Data Mining Tools Used for Water Resources Management inTigris River Analysis of Data Mining Tools Used for Water Resources Management inTigris River, (October 2018). https://doi.org/10.7508/AMS-V3-N2-1-10

Science, C. (2017). a Comparative Analysis for Smart Water Resource Using, *5*, 24–30. https://doi.org/10.5281/zenodo.840201

Teixeira Júnior, L. A., Souza, R. M. de, Menezes, M. L. de, Cassiano, K. M., Pessanha, J. F. M., & Souza, R. C. (2015). Artificial Neural Network and Wavelet Decomposition in the Forecast of Global Horizontal Solar Radiation. *Pesquisa Operacional*, *35*(1), 73–90. https://doi.org/10.1590/0101-7438.2015.035.01.0073

Vergé, X., VanderZaag, A., Smith, W., Grant, B., & Gordon, R. (2017). The consideration of time step in calculating grey water footprints of agricultural cropping systems. *Ecological Indicators*, *78*, 31–36. https://doi.org/10.1016/j.ecolind.2017.03.006

Wang, J., & Liu, S. (2018). Knowle dge-Base d Systems Novel binary encoding water cycle algorithm for solving Bayesian network structures learning problem. *Knowledge-Based Systems*, *150*, 95–110. https://doi.org/10.1016/j.knosys.2018.03.007

Wickramasinghe, W. M. S., Navaratne, C. M., & Dias, S. V. (2018). Building resilience on water quality management through grey water footprint approach: A case study from Sri Lanka. *Procedia Engineering*, *212*, 752–759. https://doi.org/10.1016/j.proeng.2018.01.097

Xu, M., Li, C., & Lu, S. (2017). Sustainable Water Resources Utilization on Energy Industry Based on the Gray Water Footprints Assessment in Hunan Province. *Energy Procedia*, *105*, 3758–3764. https://doi.org/10.1016/j.egypro.2017.03.872

Zhi, Y., Yang, Z., Yin, X., Hamilton, P. B., & Zhang, L. (2015). Using gray water footprint to verify economic sectors ' consumption of assimilative capacity in a river basin : model and a case study in the Haihe River Basin , China. *Journal of Cleaner Production*, *92*, 267–273. https://doi.org/10.1016/j.jclepro.2014.12.058